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Medical Image Viewing Over Mobile Devices Using 3G Network

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ABSTRACT

The future of healthcare delivery systems and telemedicinal applications has undergone a tremendous change due to e-health. E-health was the result of the integration of networks and telecommunications, dealing with applications of collecting, sorting and transferring medical data from distant locations for performing remote medical collaborations and diagnosis. Medical information is either in multidimensional or multi resolution form, this creates enormous amount of data. Efficient storage, retrieval, management and transmission of this voluminous data is extremely complex. The solution is to reduce this complexity is to compress the medical data so that the diagnostics capabilities are not compromised. For medical images, only a small portion of the image might be diagnostically useful, but the cost of a wrong interpretation is high. Combination of Lossless and Lossy compression schemes with secure transmission play a key role in telemedicine applications that help in accurate diagnosis and research. In this paper, we propose a combined compression method for Digital Imaging and Communications in Medicine images. The method includes the compression of region of interest using lossless image compression technique i.e. Predictive coding while the remaining area of image (other than region of interest) is compressed using the near lossless image compression techniques i.e. DCT. The image later is reconstructed by merging the region of interest with non-region of interest to get the compressed image, which is then sent over a wireless network using a 3G connection for fast and errorless transmission, to be accessed by authorized users on mobile devices.

Introduction

Telemedicine applications involve image transmission within and among health care organizations using public networks. This requires compressing the data as well as handling of security issues for storage, retrieval and distribution of medical data. In order to provide a reliable and efficient means for storing and managing medical data computer based archiving systems such as Picture Archiving and Communication Systems (PACS) and Digital-Imaging and Communications in Medicine (DICOM) standards were developed. With the huge increase in the number of images acquired for diagnostic purposes, the importance of compression has become invaluable in maintaining and protecting medical images and health records.

Image compression is the application of data compression on digital images. Two fundamental components of compression are redundancy and irrelevancy reduction. The main purpose of image compression is to reduce the redundancy and irrelevancy present in the image, so that it can be stored and transferred efficiently Redundancy reduction aims at removing duplication from the signal source (image/video). Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System (HVS).

There are two main reasons for compression of the image:

1. Large amount of image data is produced in the field of medical imaging. A medium scale hospital with routine facilities produces on an average 10 GB to 20 GB of data. So, it is really difficult for hospitals to manage the storing facilities which includes storage space as well as retrieval for the such amounts of data.

2. Such large data demands for high end and superfast network especially for transmitting the images over the local network such as in telemedicine. Increasing the bandwidth is another method, but the cost makes this a less feasible solution.

So here we propose a method (outline in figure-1) for efficient storage and retrieval of medical images that aims at preserving diagnostically important data as well as error free retrieval over a wireless connection.

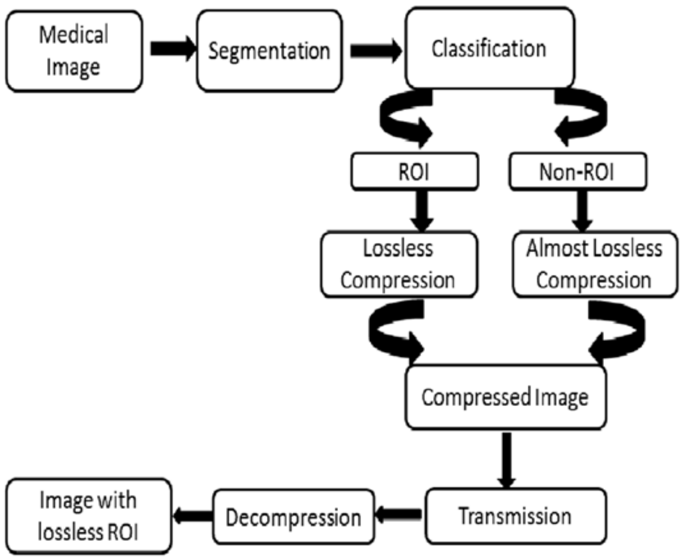

Figure 1. Flow chart of proposed method

DICOM Images

DICOM (Digital imaging and communication in medicine) is a standard for handling, storing, printing and transmitting information in medical imaging. It includes a file format definition and network communication protocol. DICOM file

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can be exchanged between two entities that are capable of receiving image and patient data in DICOM format.

DICOM was created by the National Electrical Manufacturers' Association (NEMA), to improve compatibility and workflow efficiency in a hospital environment. This has become the principal standard for the communication of medical images. The basic difference between a DICOM image and an image in other formats like JPEG, TIFF, GIF is that DICOM image contains a 'header' with information (such as patient demographics, machine, scan parameters, and a host of other non-image data).DICOM image also contain image data .

The adoption of DICOM standards for medical imaging equipment has helped in effective cross-machine communications and made possible integration of imaging equipment from different manufacturers. However due to the particularity of the DICOM image format, the common image processing software cannot display, process and convert this file format.

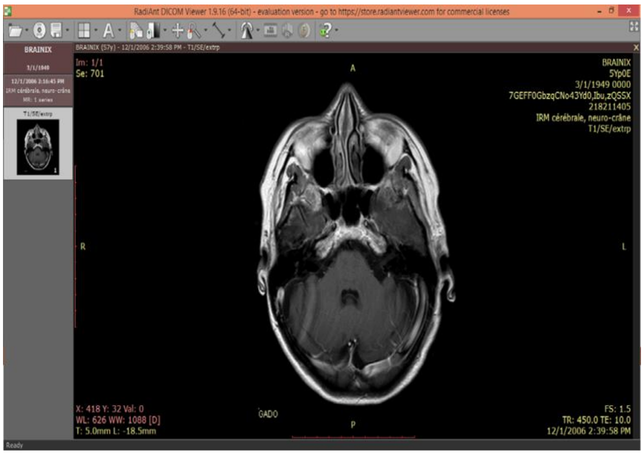

Figure 2. DICOM image

Image Segmentation

Image segmentation is a process in which regions or features sharing similar characteristics are identified and grouped together. The main goal of image segmentation is domain independent partitioning of an image into a set of disjoint regions that are visually different, homogeneous and meaningful with respect to some characteristics or computed property such as grey level, texture or color to enable easy image analysis. Image segmentation techniques used in our work were

1. Threshold based
2. Active Contour Based
3. Region Based

Results for Image Segmentation

Threshold based segmentation

Threshold is useful in separating foreground from the background. By selecting an adequate threshold value T, the gray level image can be converted to binary image. The advantage of obtaining first a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification.

The most common way to convert a gray-level image to a binary image is to select a single threshold value (T). Then all the gray level values below this T will be classified as black (0), and those above T will be white (1). The problem faced in this method is of selecting the proper value for the threshold T.

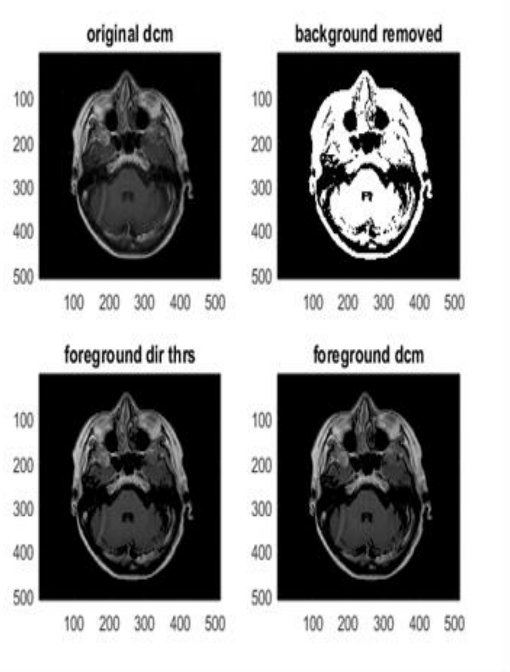

Figure 3.results for Direct Thresholding

The above mentioned Direct Thresholding uses a global threshold for all pixels, whereas Adaptive Thresholding changes the threshold dynamically over the image.

Adaptive Thresholding typically takes a gray scale or color image as input and, outputs a binary image representing the segmentation. For each pixel in the image, a threshold is calculated, if the pixel value is below the threshold it is set to the background value, otherwise it is assigned the foreground value. Approach to find the local threshold is to statistically examine the intensity values of the local neighborhood of each pixel. The statistic (mean, median etc) which is most appropriate depends largely on the input image.

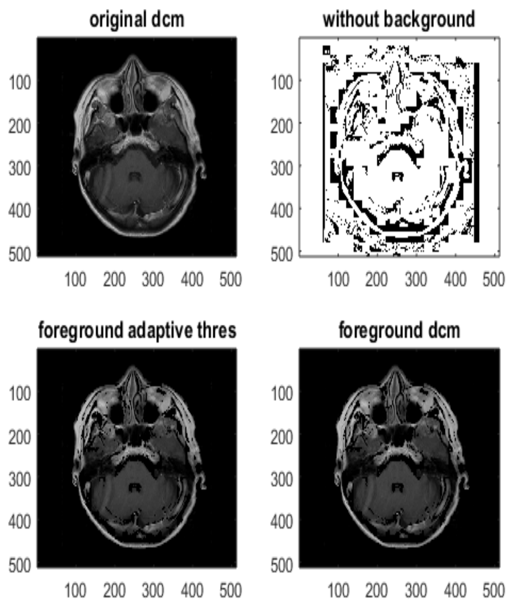

Figure 4. Results for Local Adaptive Thresholding

Active Contour based segmentation

In segmentation using active contours model the user specifies an initial guess for the contour, which is then moved by image driven forces to the boundaries of the desired objects. Since it is based on initial guessing it is not suitable for medical images as all images don't necessarily lie within same guessed contour, as a result important details might be lost.

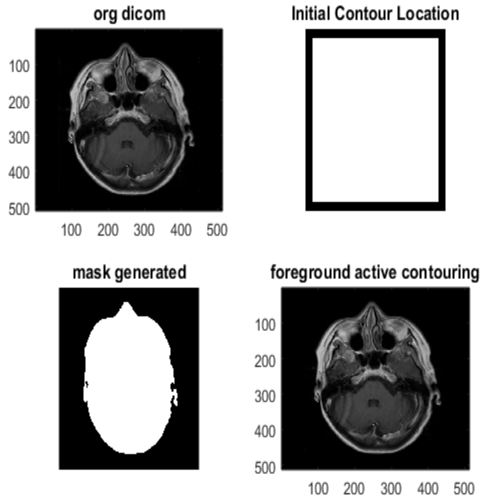

Figure 5. Results for Segmentation by active contouring

Region of Interest

In medical image all the regions do not show equal importance from examination point of view. Regions of an image which are given more consideration as compare to other regions because of their containing more important data are called region of interest i.e. ROI. In medical diagnosis, the Region of Interest (ROI) concept is important because of the limitation of medical images due to lossy and lossless compression techniques.

The compression ratio of lossless compression techniques are very small, while for the lossy techniques compression ratio is much greater, but causes loss in the data and also this loss in data may distort the important part of medical image. So to get rid from this problem, a better compression technique is needed which is obtained by lossy compression of Non ROI and lossless compression of ROI.

To apply this combination of compression, segmentation is the first stage to define the ROI. It can be done manually to achieve greater degree of accuracy, where the physician tracks the contours (e.g. using a mouse) to provide the ROI.

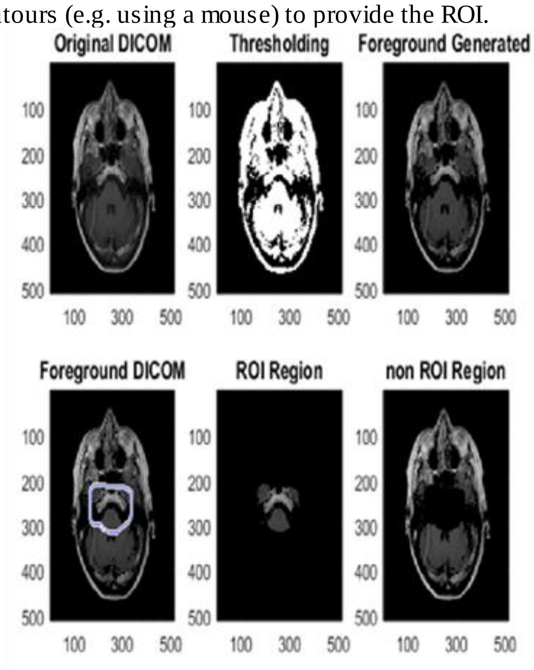

Figure 6. Parts of medical image generated by segmentation

Image Compression

Compression is reducing the quantity of data used to represent a file, image or video content without reducing the quality of the original data excessively or at all. Image compression is the application of data compression on digital images.

The compressed image is represented by less number of bits compared to original thus the required storage size will be reduced, consequently maximum images can be stored and it can transferred in faster way to save the time and transmission bandwidth. Hence compression of image plays an important role in medical field for efficient storage and transmission. Compression is achieved by the removal of one or more of three basic redundancies:

1. Coding redundancy, which is present when less than optimal (i.e. the smallest length) code words are used.
2. Interpixel redundancy, which results from correlations between the pixels of an image.
3. Psycho visual redundancy which is due to data that is ignored by the human visual system (i.e. visually nonessential information).

Image compression includes three general steps:

Transformation

For image compression, the selection of transform should reduce the size of resultant data set as compared to source image data. Some transformations reduce the number of data items in the data set while some transformations reduce the numerical size of the data items that allows them to represent by the fewer binary bits. In data compression, transform is intended to decorrelate the input signals. The data represented in the new system has properties that facilitate the compression encoding. The transform methods applied in the proposed work are Discrete Cosine Transformation and Wavelet Transformation.

Quantization

In the process of quantization each sample is scaled by the quantization factor to get approximate values corresponding to quantization levels, whereas in the process of thresholding, samples are eliminated if the value of sample is less than the defined threshold value. Although these two methods are responsible for introduction of error and it leads in degrading the quality, but they reduce the computation time hence preferred in lossy compression method.

Encoding

This phase of compression reduces the overall number of bits needed to represent the data set. Encoder further compresses the quantized values to give better overall compression. This process removes redundancy in the form of repetitive bit patterns in the output of quantizer. It uses a model to accurately determine the probabilities for each quantized value and produces an appropriate code , based on these probabilities so that the resultant output code stream will be smaller.The encoding determines if the compression is lossy where it removes redundancy as well as irrelevant data or lossless which removes only redundant data. For lossy we have used SPIHT and DCT encoding and for lossless we have used Predictive Huffman encoding bandwidth. Hence compression of image plays an important role in medical field for efficient storage and transmission. Compression is achieved by the removal of one or more of three basic redundancies:

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Results For Combination of Image Compression Techniques on ROI & Non ROI

Since we are using ROI based image compression to preserve diagnostically important data, a pair of compression technique is applied on ROI and Non ROI, to reduce the size of otherwise very large dicom image of size more than 500 KB to less than 90 KB. The combination of techniques used for image compression on dicom image of size 548 KB are:

1. SPIHT on Non ROI and Predictive Huffman with Wavelet Transform on ROI, Both ROI and Non ROI are in dicom format, to get the final image of size 60KB ie image is reduced by 89.06%

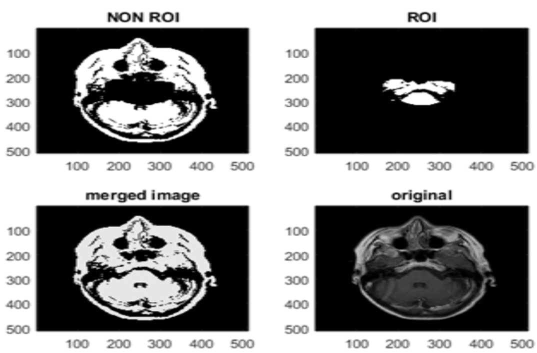

Figure 7. Results with PSNR performance of 2.50 dB

2. DCT on Non ROI & Predictive Huffman with wavelet transformation on ROI to get the compressed image of size 84KB ie reduced by 84.68%

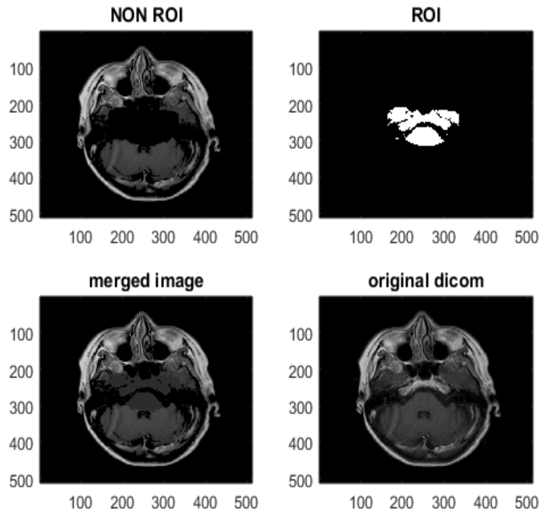

Figure 8. Results with PSNR performance of 10.50 dB

3. DCT on Non ROI & Predictive Huffman with no transformation on ROI to get the compressed image of size 89KB ie reduced by 83.76%

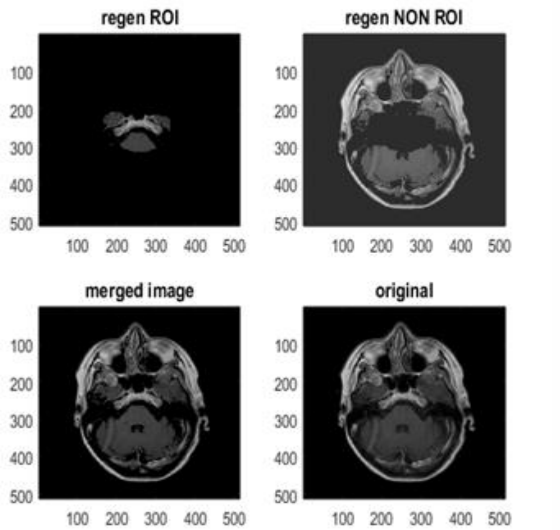

Figure 9. Results with PSNR performance of 13.65 dB

4. SPIHT on Non ROI and Predictive Huffman with Wavelet Transform on ROI, where ROI is in bmp and Non ROI are in tif format, to get the final image of size 26KB ie image is reduced by 95.26%

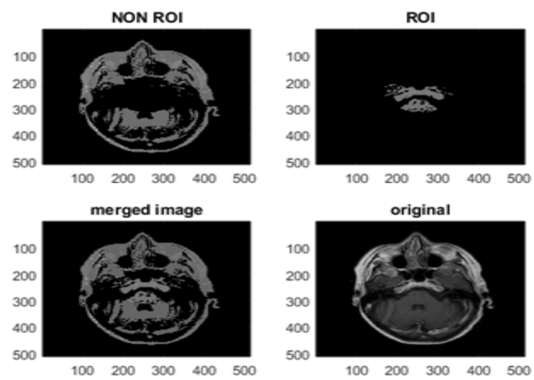

Figure 10. Results with PSNR performance of -1.46 dB

5. SPIHT with wavelet transform on Non ROI and Predictive Huffman with wavelet transform on ROI, where ROI is in dicom format and Non ROI is in tif format, compressed to get the final image of size 90KB ie image is reduced by 83.58%

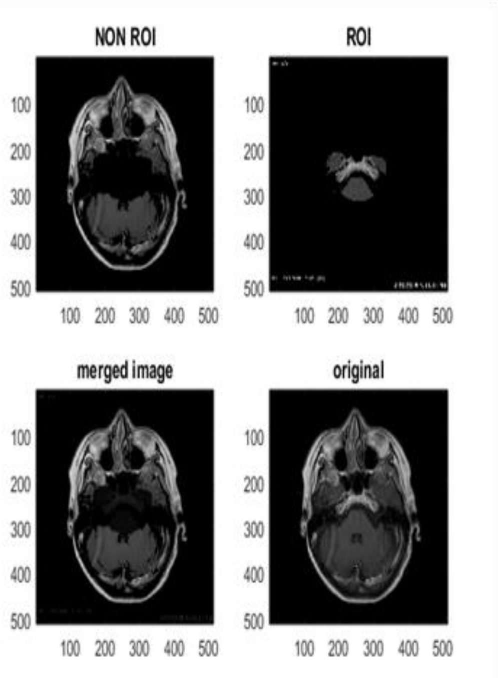

Figure 11. Results with PSNR performance of 8.31 dB

Selection of a Pair of Compression Method for Non ROI & ROI

Selection of final compression technique pair was made on the basis of (in order of priority):

1. Visual Results
2. PSNR ratio
3. Percentage Reduction in size

The results are summarized in given Table 1.

Based on the results in Table 1, Discrete Cosine Transformation on Non ROI in dicom format & Predictive Huffman without wavelet transform on ROI in dicom format was selected, as the visual resemblance to original image was very high, noise was very less as compared to others as the PSNR ratio was highest among all and reduction in image size was also desirable.

Although the only problem faced is that it takes comparatively longer to perform lossless compression on ROI (about 70-90 seconds on 545 KB size dicom image) as no transformation is performed which quantizes the pixel values to fall in the approximate levels.

Transmission & Retrieval

Transmission of data of any form text, image or multimedia over a network requires data to be stored at a server and be available to its intended users, thus for data to be communicated it has to be stored then retrieved and transmitted .Digital communication is used in wide applications for successful multimedia communication to handheld devices, such as Mobile Phones, PDAs etc. To transmit precise and errorless data, one must need to compress data for efficient transmission, enable secure access to data as well as to encode data for errorless transmission through noisy channels.

Data Storage and Retrieval

To provide remote access to data over a network, it has to be present on a server, where data is stored in databases in form of tables. All details relevant to a patient are uploaded to the server which can be accessed over internet, but we must provide means to ensure only authorized access to this data. Although it increases the complexity of scripting code but security of data is always a primary concern of all web deployments. Besides here the nature of data is critical, any unauthorized modification or manipulation can be disastrous to healthcare system, even disclosure of patient data to any third party is considered unethical. Hence the access to the system is controlled by username- password authentication.

Username-password authentication

Here only users who know the username (Patient Id's in our project) and have the knowledge of password that governs the profile of each user can login to the system. It basically uses a PAP- Password Authentication Protocol to validate users before allowing them access to server resources. Existing password authentication can be categorized into two types:

1. Weak password authentication schemes
2. Strong password authentication schemes

When compared to strong-password schemes weak password schemes tend to have lighter computational overhead, the designs are simpler and implementation easier making them specially suitable for some constrained environments like limited networking speeds or limited computational time.

Figure 13. GUI for member login

Image storage & retrieval

Images can be stored on a remote server in two most generalized manners:

1. Storing in a database
2. Storing on the server directly

When storing image in database we have to upload an image, retrieve its various parameters like size, name, type and content, and then store each of these separately in different columns of the database. The main Content of image is stored as a Binary Large OBject (BLOB) which is a collection of binary data stored as a single entity in a database management system. Blobs can be critical images, audio or other multimedia objects, though sometimes binary executable code is also stored as a blob. For storage to blob field the image data has to be processed into binary format then uploaded to database. This incurs extra processing of data on the server as the image has to be parameterized, processed then stored. Similarly reverse has to be done on retrieval from database. While storing image contents to a database makes the image data more secure but storing image as BLOB on database has three major drawbacks:

1. This results in huge database size.
2. The queries required to store, retrieve and process blob are huge and computationally costly and can cause application slowdown in case of slow network speeds.
3. Exposing image parameters to large amount of processing, results in more chances of errors in regenerated images.

Fig.14.GUI for displaying and downloading the medical image

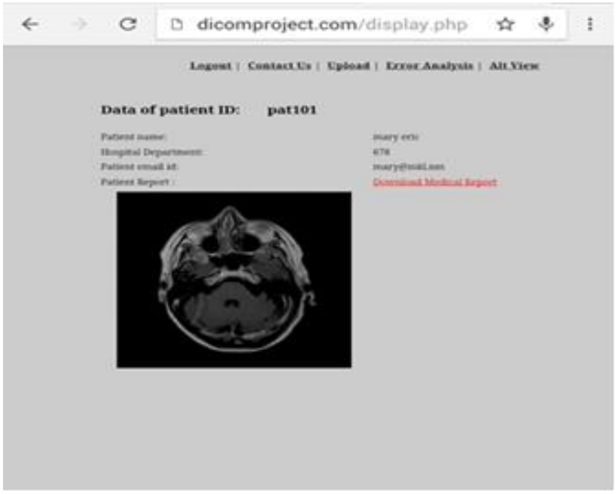

Figure 14. GUI for displaying and downloading the medical image

When storing image directly on the server we have to upload the image, store it in a file system on the server and only store its link to the server in the database to relate the image to the particular user id. There is no need to retrieve its various parameters like size, name, type and content; although we can do it for image validation purpose to add security to image. This message however is not as secure as storing as BLOB in database as it provides direct access to the database. But in application like telemedicine where only few users are authorized to upload images this doesn't pose a serious threat. Also here the image is not broken into parts and then stored this results in very less or no chances of errors as here image is directly viewed or downloaded from the link to its file system on the server, which is of more use in telemedicine application as here image quality is primary concern. This also makes the method more efficient in terms of computation cost, database size and query generation.

Channel Coding

The aim of channel coding theory is to find codes which transmit quickly, contain many valid code words and can detect and/or correct few errors. However, performance in terms of computation time and processing ability in this areas is a tradeoff. Channel coding introduces controlled redundancy into a transmitted binary data stream in order to increase the reliability of transmission. The requirement of a channel coding scheme only exists because of the noise present in the channel. Simple channel coding schemes allow to detect errors, while more advanced channel coding schemes provide the ability to recover a finite amount of corrupted data. This results in more reliable communication, and may eliminate the need for retransmission. Although channel coding provides many benefits, there is an increase in the number of bits being transmitted.

Hamming distance

The Hamming distance between two biary strings of equal length is the number of positions at which the corresponding symbols are different. In another way, it measures the minimum number of substitutions required to change one string into the other, or the minimum number of errors that could have transformed one string into the other.

A major application is in coding theory, more specifically to block codes. For binary strings a and b the Hamming distance is equal to the number of ones (population count) in a XOR b.

The Hamming distance is used to define error detecting and error correcting codes. A code C is said to be k-errors detecting if and only if the minimum Hamming distance between any two of its codewords is at least k+1. A code C is said to be k-errors correcting if and only if the minimum Hamming distance between any two of its codewords is at least 2k+1. Thus a code with minimum Hamming distance d between its codewords can detect at most d-1 errors and can correct (d-1)/2⌋ errors.

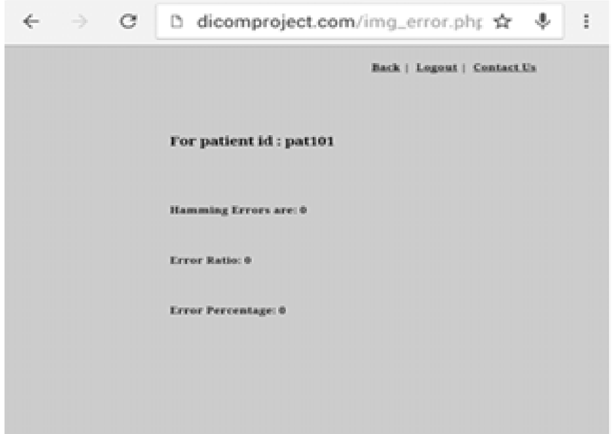

Figure 15. GUI for determining hamming distance between the downloaded medical image and one stored in database

Hamming code

Hamming code is a set of error-correction code that can be used to detect and correct bit errors, it makes use of the concept of parity bits, which are bits that are added to data so that the validity of the data can be checked when it is read or after it has been received in a data transmission. Using more than one parity bit, an error-correction code can not only identify a single bit error in the data unit, but also its location in the data unit.

In data transmission, the ability of a receiving station to correct errors in the received data is called forward error correction (FEC) and can increase throughput on a data link when there is a lot of noise present. However, the correction may not always represent a cost saving over that of simply resending the information.

The number of parity bits required depends on the number of bits in the data transmission, and is calculated by the Hamming rule:

$$P\ d + p + 1 < = 2 \quad (1)$$

Where d is the number of data bits and p is the number of parity bits.

In the Hamming code we applied, we used (7,3)- Hamming code which encoded 4 bits into 7, i.e. introduced 3 parity bits to each 4-bit codeword and could detect upto 2 bit errors and correct 1 bit error for each 4 bits of input binary string of the medical image.

Major drawback in implementation of hamming code on binary form of image data:

Since it takes image data in bits, the image consists of more than 85000 bits in binary form, thus comparing two such images requires very large processing power and a large amount of time. To implement such a code on a normal configuration system can result in resource overused warnings, or even system crashes.

For instance when we ran the code for hamming correction over local host configuration of 1000 seconds as maximum execution time (default is 60 seconds) and memory limit of 528MB (default is 128 MB) for only three iterations i.e 12 bits resulted in "Fatal error: Maximum execution time of 1000 seconds exceeded.."

Table 1. Performance Metric of different compression coding techniques

Compression Pair	Performance Attribute		
	Visual Results	PSNR (dB)	Reduction in size (%)
SPIHT & Huffman both with WT on dcm	Binary Image	2.50	89.06
DCT & Predictive Huffman with WT	Grayscale with noisy ROI	10.50	84.68
DCT & Predictive Huffman without WT	Grayscale with no noise	13.65	83.76
SPIHT & Huffman both with WT on bmp	Grayscale noisy with loss of information	-1.46	95.26
SPIHT on tif & Huffman on dcm, both with WT	Grayscale with information in ROI	8.31	83.58

Conclusion

Every image contains some redundant information, which needs to be identified to obtain compression. ROI-based compression is providing better results as compared with single compression methods, along with preservation of diagnostically important information. The floating point representation of the DCT gives small error in the system. The Predictive encoding is recommended for critical medical application because of its perfect reconstruction property. Since in Telemedicine applications time constraint is not a limitation just a binding so selecting a compression method is completely based first on visual accuracy of decompressed image and second on reduction in size as DICOM images are very large to be transferred as such on a network. Advanced version of the proposed method may include the compression based on the information contents as well as compression based on ROI to be selected automatically. A method which combines usability of telemedicine application with the portability of mobile devices is recommended for telemedicine systems especially rural areas, where networks as well as medical resources have limitations or for consultation over internet (eHealth). Also the feasibility of using mobile device, as a client workstation allows authorized viewers to access patient information and data as when needed over a 3G network.

References

[1]. Gregory A. Baxes. Digital Image Processing: Principles and Applications, John Wiley & Sons Inc., New York NY, 1994.

[2]. Wayne C. Brown and Barry J. Shepherd, Graphics File Formats: Reference and Guide, Manning Publications, 1995.

[3]. Kenneth R, Castleman, Digital Image Processing, Prentice Hall, 1979.

[4]. Rafael Gonzalez and Richard E.Woods. Digital Image Processing, Addison-Wesley, 2nd edition, 2002.

[5]. Duane Hanselman and Bruce R. Littleld, Mastering Matlab 6, Prentice Hall, 2000.

[6]. Alasdair McAndrew, An Introduction to Digital Image Processing with Matlab

[7]. Bernd Jähne, Digital Image Processing , Springer-Verlag, 1991.

[8]. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989.

[9]. Ramesh Jain, Rangachar Kasturi, mand Brian G. Schunk, Machine Vision. McGraw-Hill Inc., 1995.

[10]. Arne Jensen and Anders la Cour-Harbo, Ripples in Mathematics: the Discrete Wavelet Transform, Springer-Verlag, 2001.

[11]. Dr.J.Janet, Divya Mohandass and S.Meenalosini, Lossless Compression Techniques for Medical Images in Telemedicine

[12]. Divya Neela, Lossless Medical Image Compression Using Integer Transform and Predictive Coding Technique

[13]. Gerard J. Holzmann. Beyond Photography: the Digital Darkroom. Prentice Hall, 1988

[14]. Meenakshi Chaudhary1, Anupma Dhamija2, Compression of Medical Images using Hybrid Wavelet Decomposition Technique, International Journal of Science and Research (IJSR), India Online

[15]. William K. Pratt, Digital Image Processing. John Wiley and Sons, second edition, 1991.

[16]. Jayshree S. Nandaniya,Nilesh B. Kalani, Dr.G.R.Kulkarni, Comparative Analysis of Different Channel Coding Techniques IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501

[17]. Prachi Patil, S.V.Patil and D.D.Chaudhari, Research on Conversion of DICOM Multi-Frame Medical Image in to Multimedia Format using MATLAB

[18]. Meenakshi Chaudhary1, Anupma Dhamija, A Brief Study of Various Wavelet Families and Compression Techniques

[19]. Vaishali G. Dubey, Jaspal Singh, 3D Medical Image Compression Using Huffman Encoding Technique, International Journal of Scientific and Research Publications, Volume 2, Issue 9.

[20]. Mr. Amit S. Tajne1, Prof. Pravin S. Kulkarni2 International Journal of Computer Science and Mobile Computing, International Journal of Computer Science and Mobile Computing, Vol.4 Issue.2

[21]. Tanay Mondal, Dr. Mausumi Maitra, Denoising and Compression of Medical Image in Wavelet 2D, International Journal on Recent and Innovation Trends in Computing and Communication Volume: 2 Issue: 2

[22]. Carrison K. S. Tong, Eric T. T. Wong Mobile Medical Image Viewing Using 3G M Wireless Networks.

[23]. Prabhjot Kaur , Sarbdeep Singh, Image Compression Using Multithresholding Technique to Enhance Huffman Technique, International Journal of Scientific & Engineering Research Volume 3, Issue 8, August-2012 1 ISSN 2229-5518

[24]. Vinayak K Bairagi and Ashok M Sapkal, ROI-based DICOM image compression for telemedicine

[25]. Nooshin Boroumand Jazi, Mohamad Davarpanah Jazi , Homayoun Mahdavinasab, ROI-based DICOM Image Compression, Majlesi Journal of Multimedia Processing Vol. 3, No. 2, June 2014

[26]. Shilpa Kamdi1, R.K.Krishna, Image Segmentation and Region Growing Algorithm, International Journal of Computer Technology and Electronics Engineering (IJCTEE) Volume 2, Issue 1

[27]. Y.Sukanya, J.Preethi, Analysis Of Image Compression Algorithms Using Wavelet Transform With Gui In Matlab, IJRET: International Journal of Research in Engineering and Technology